

Grain Size Studies on the Nearshore Sediments of Jaigad, Ambwah and Varvada Bays, Maharashtra

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Abstract: Bivariate plots of the textural parameter data suggest overlapping environments, such as river/beach to JB, beach/dune/river to AB and dune/beach to VB sediments.

Keywords: Sedimentology, Grain size parameters, Depositional Environments, Bays, Maharashtra.

INTRODUCTION

Grain size parameters have been employed for characterising and recognising various depositional processes and environments. Scatter diagrams using textural variables, calculated by graphical measures (Flok, 1984) and moment measures (Friedman, 1979) have also been made use of. Visser (1969) has proposed study of the subpopulations and hydrodynamics. An effort has been successfully made by Rajamanickam and Gujar, using textural parameters (1984), multigroup discrimination of different depositional environments (1983) and Visser's subpopulations (1993) to the bays situated further south of the study area. In this paper, we attempt to understand the possible changes in the depositional environments within the bays of Maharashtra through bivariate plots and probability curves.

MATERIALS AND METHODS

256 samples approximately at intervals of 200 m grids, using a Van Veen grab (area 0.46 cm²), were collected in three adjacent bays, namely JB, AB and VB (Fig.1), JB receives sediments from Shastri river, being a major river in the region and VB receives sediments sparingly through the Varvada creek while AB has no land source (Table I). 97 representative

sediment samples from the three bays (JB - 54, AB - 21 and VB - 22) have been subjected to textural studies.

RESULTS AND DISCUSSION

The range and average grain size data obtained from 97 sediment samples of different bays, employing both graphic and moment measures are utilised. Following the earlier studies of similar nature (Rajamanickam and Gujar, 1984) for kurtosis alone both graphic and moment measures have been utilised. Otherwise, results of graphic measures have been made use of.

Distribution of Textural Parameters

Figure 2 (A) depicts the distribution of mean grain size. In VB, sands are characterised by a size range of 2.0 to 4.0 ϕ but in AB, it is less than 2.0 ϕ , and in JB on the other hand, sediments of less than 2.0 ϕ are distributed over a wider area. A gradual seaward decrease in grain size is observed in VB and AB whereas in JB it does not show any such pattern, probably, because of the large fluctuation in the volume and the nature of the debris, brought in by the Shastri river and by the appreciable tidal effects in the channel.

Frequency curves (Fig.4C) were prepared

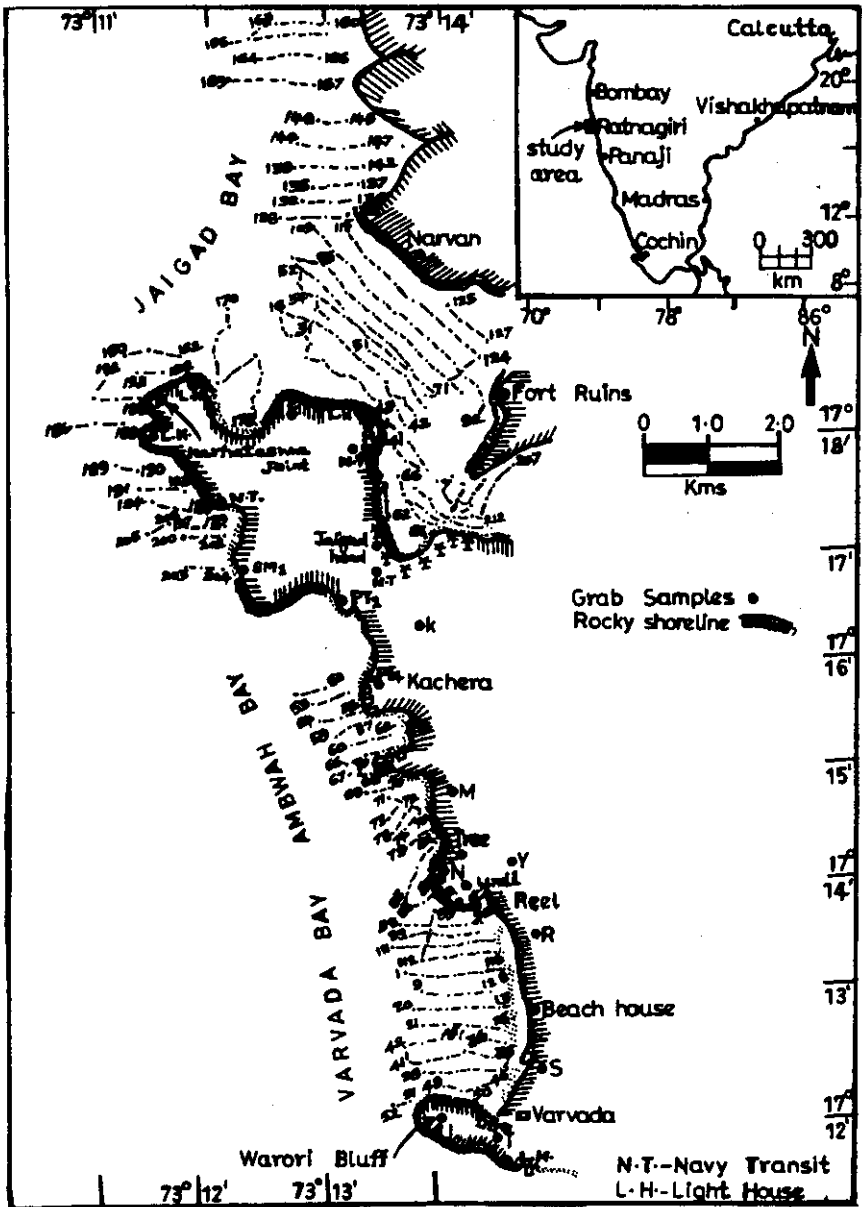


Fig.1. Sample Locations

for the sieve data along selected transects for each bay. A sharp single peak in the frequency curves for AB and VB suggests unimodal nature while the broad peaks in the JB sediments depict poorly sorted nature. For many samples from JB, the peaks lean to the right

indicating river deposition. The nature of peak which appears between 2 and 3 ϕ , remains rather uniform for all the samples of AB and VB but in JB, it changes from sample to sample.

The best sorted sediments are those with mean size range of about 2.0 to 3.0 ϕ and

Table I. Characteristic features of Jaigad, Ambwah and Varvada Bays

| | Jaigad (JB) | Ambwah (AB) | Varvada (VB) |
|---------------------------------|--|--|---|
| Location | 17°21'30"N : 17°17'30"N 73°08'18"E : 73°14'36"E | 17°17'30"N : 17°13'50"N 73°10'00"E : 73°13'12"E | 17°13'50"N : 17°17'40"N 73°13'54"E : 73°11'00"E |
| Area | 109 km ² | 53 km ² | 52 km ² |
| River and its catchment | Centre (Shastri river) 600 km ² | Nil — | South Varvada Creek 40 km ² |
| Promontories | North & South | North | South |
| Nature of beach | In the south rocky while north is highly irregular. | Irregular sandy and pocket beaches | Straight sandy — |
| Wind | Closed and protected from wind | Open and exposed to wind | Semiclosed and partly protected from wind. |
| Channel | Prominent tidal inlet is present | Nil | Only one small shoal in the south at 9 m depth. |
| Wave refraction | Wave convergence is in the south while in the north is divergence | Wave divergence | Wave convergence is in the south while north is diverging |
| Littoral | Northerly but within Boria bluff | Within Jaigad head to Warori bluff? | |
| Common features | Depths Tide | 10 - 22 m, Rain fall 2000 - 2500 mm. 1-2 m waves - WSW, W, WNW & SW with period 5 - 14 sec. | |
| Direction of Sediment movement: | Northerly for SW waves while southerly for WNW waves and multidirectional for all other waves mentioned above. | | |

having a smaller standard deviation of about 1.0 ϕ . From the standard deviation values, the sediments in JB are inferred to be very well sorted to very poorly sorted while AB and VB are of very well sorted to poorly sorted.

The distribution of standard deviation is shown in Fig. 2 (B). All along the river mouth, channel and offshore, poorly sorted sediments are prevalent in JB. This is probably, due to mixing of terrigenous coarser or finer materials, regularly brought in by the river. In AB, there is gradual improvement in sorting, as the mean grain size progressively decreases. Poor sorting is found nearshore, where a coarse population is introduced through the creek at Kachera village. The creek bed as well as the drainage basin are primarily, made up of weathered products of boulders, pebbles and massive basalts, thereby, reducing the possibility of supply of finer sediments. Unlike the

other bays, VB is dominated by well sorted sediments except at the mouth of the creek, where coarser shell fragments might have induced poor sorting. The sorting becomes poorer in the offshore areas where mixing of finer populations, brought in by the waves and currents due to shoreward migration of offshore sediments, are expected.

The skewness of offshore samples from the northern extremity of the bays are fine-skewed (Fig.2C). The same may be due to the excessive supply of fine material, brought in by the littoral currents. Sediments from the Shastri river channel and minor creeks in AB, Kachera and VB are either strongly coarse-skewed or subjected to the removal of the coarser light fraction. It facilitates the concentration of finer heavier grains. The latter alternative is supported by the higher concentration of heavy minerals and the presence of wave conver-

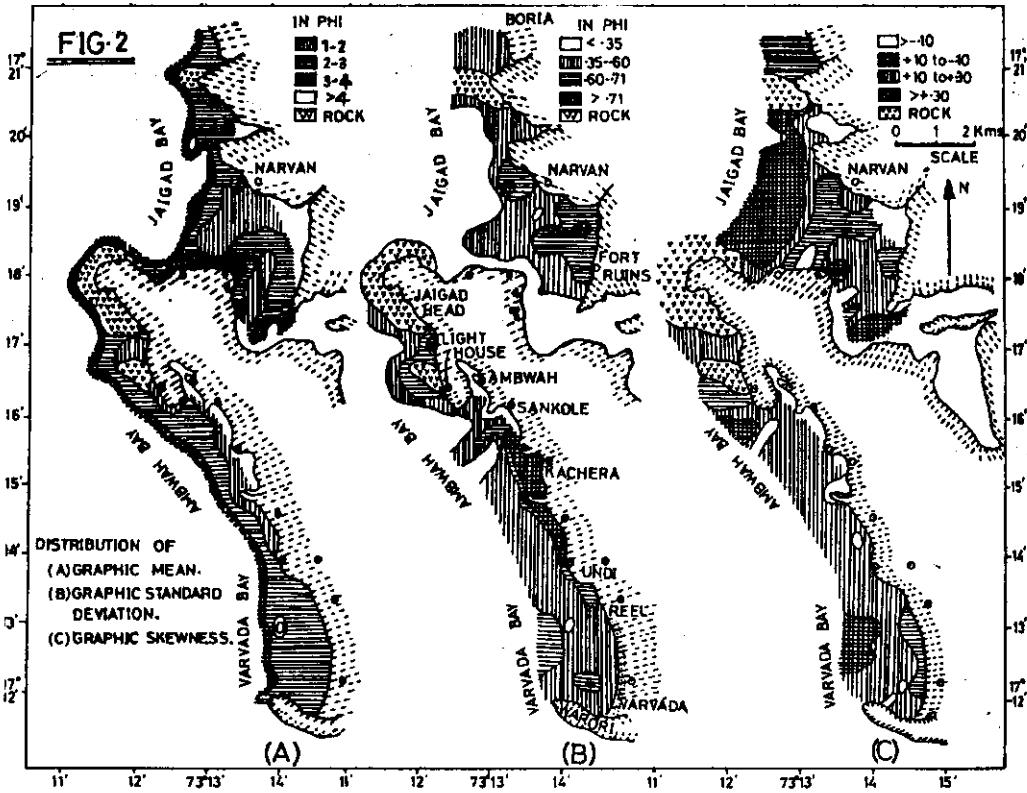


Fig.2. (A) Distribution of graphic mean, (B) Distribution of graphic standard deviation, (C) Distribution of graphic skewness.

gence in this area. AB sediments remain near symmetrical in distribution. That is possible only in the absence of extreme conditions like wave breaking, tidal variations, seasonal supply of detrital materials, etc. Gradual variation in the distribution of mean grain size and standard deviation also indicate limited winnowing action and a normal distribution of sediments, having seaward decrease of grain size. Unlike the AB and VB, the JB shows a high order of variability in the distribution of skewness. Such a high variability may be attributed to the factors like large influx of sediments from the Shastri river, the removal of finer materials due to the prevailing wave convergence around Jaigad head and strong tidal currents around the river mouth (Rajamanickam, *et al.* 1986), and the selective

deposition in the northern part of the bay due to the wave divergence existing in the area.

Figure 3 (A) shows, distribution of graphic kurtosis. When the verbal limits of Folk (1984), are applied to VB and AB sediments, they are mainly leptokurtic to extremely leptokurtic, whereas JB sediments vary from very leptokurtic to very platykurtic. Sediments of the JB channel and Kachera creek mouth are very leptokurtic because of the strong mixing of the fluvial sediments. The sediments of northern part of the AB gradually, change from very leptokurtic to very platykurtic as the sediment sorting deteriorates seaward. In JB, the sediments become very leptokurtic to mesokurtic from the river mouth to the centre of the bay and mesokurtic to leptokurtic from the centre of the bay to the offshore areas. Such

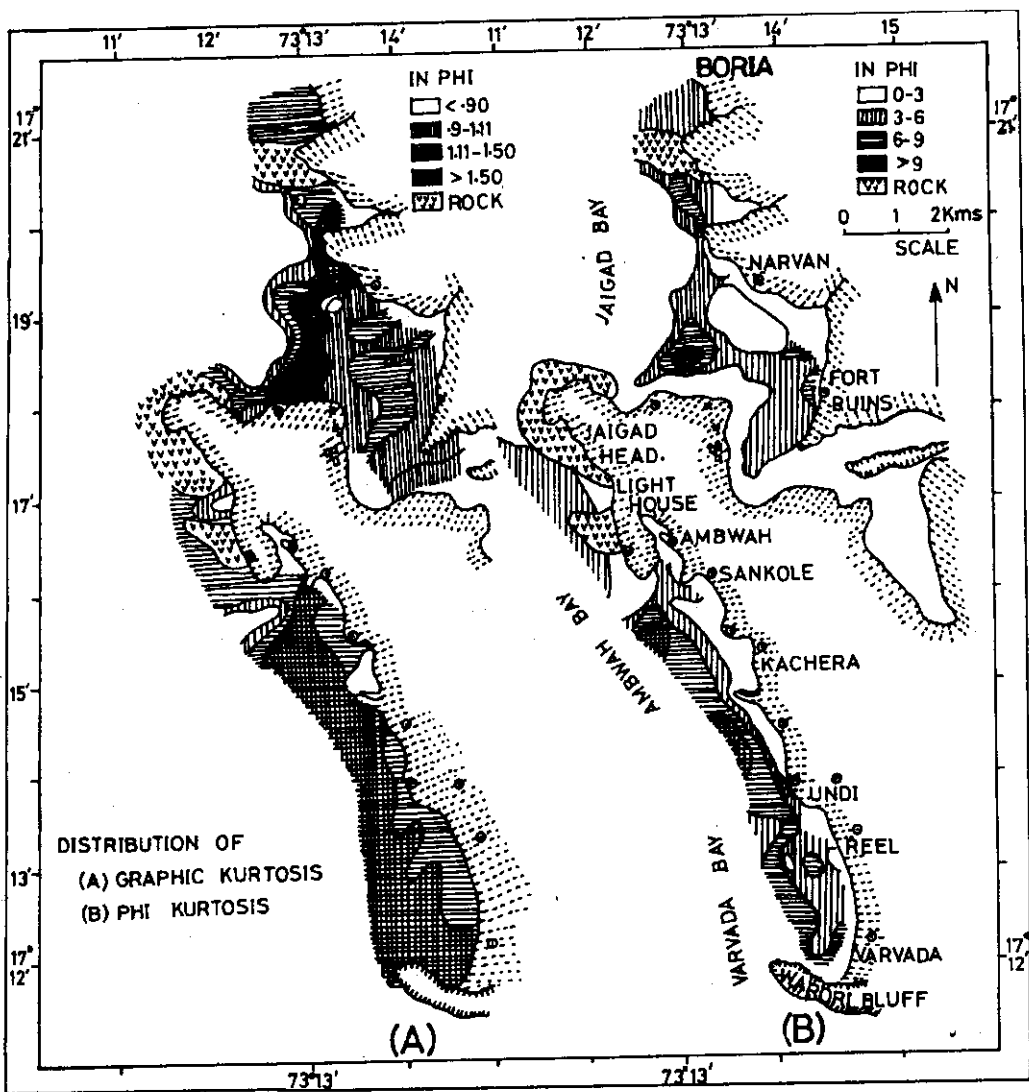


Fig.3. Distribution of (A) Graphic kurtosis and (B) Phi Kurtosis.

changes in the kinds of sediments are due to the mixing of two environments of two different populations, one derived from riverine environment and the other primarily, from marine environment, supported by the presence of appreciable percentage of heavy minerals not related to basalts. In the offshore the finer populations are being modified from the high energy riverine environment to the low energy conditions in the centre of the bay. In the bay

mouth, coarse populations originated in the riverine environment are being transformed into low energy but marine conditions. In brief, kurtosis values of JB sediments are typically indicative of the mixing of two end populations, whereas in the other bays such mixing is very insignificant.

Kurtosis values by moment measure vary from 1 to 11 in the sediments of the three bays (Fig.3B). In VB sediments, kurtosis values

generally, increase seawards except in the northern portion, where a topographical high is located. Figure 2 (A) also establishes the effect of such high by an isolated patch of accumulation of fine sediments. The gradual increase in kurtosis values may be taken as a measure for the amount of mixing of two end populations. The variation of kurtosis in AB sediments is more or less similar to the normal distribution of sediments as in the case of Irish sea (Cronan, 1972). Plot of kurtosis of JB sediments shows a circular distribution pattern suggesting a diversion of finer population in a circular pattern so as to get deposited in the centre, where the magnitude of the current speed is relatively less, as the zone falls behind the bar and by the side of the promontory. This zone is also found to be the closing point of the channel and forms the northern bank of the JB channels. This channel relation may be correlated to the northern Bristol channel where eddies produced by tides cause the deposition of fine-grained material at their centre due to reduction in the magnitude of the current speed, bed shear stress and turbulence (Barrie, 1981). The increase of kurtosis in the offshore in the south of the promontories in AB and VB also may lead to the change in the tidal eddies caused by the promontories.

The distribution of different grain size parameters clearly brings out the variation in the nature of sediments. In that, JB sediments behave distinctly by showing high order of mixing of the two end populations and poor sorting with very platykurtic nature; the frequency curves indicated the riverine environment. AB sediments show limited mixing, moderate sorting and leptokurtic peakedness, while the VB sediments are typified by the well sorted nature with the very leptokurtic peakedness and poor mixing of the end populations. In Fig.3 (B) kurtosis values of AB show an increase in the offshore in two places where fine sediments are brought in by the wave divergence and mix with the existing population there, whereas in the VB kurtosis values

show a decrease in the northern part i.e. off Undi, due to the removal of fines at the wave converging point. The results of wave refraction studies (Rajamanickam, *et al.* 1986) are very well matching with the decrease of kurtosis values in all the places where the wave convergence is primarily, noticed especially, just around the promontories (Fig.3B).

Depositional Environment through Bivariate Plots

Past studies by many workers have shown that representative fields of a particular modern environment can be separated by bivariate plots of one sediment size descriptor against another. The authors are of the opinion that since difference between the graphic and moment measures are relatively small, the environment boundaries of Friedman (1979) and that of Moliola and Weiser (1968) if taken together, will perhaps be reliable tool for identifying the different environments of sedimentation. On this basis, six different successful scatter plots (Figs.4 & 5) of various workers have been chosen for recognising the environments of different sediments in the different bays.

The plot of skewness vs standard deviation (Fig. 4A) indicates the concentration of JB samples around '0' skewness while the other two bay samples show a gathering around the skewness value of 0.25. If BVT (Bivariate) boundary between two environmental envelopes (Friedman, 1967) is superimposed on Fig.4 (A), the JB samples lie mainly in the river zone while other two fall within the beach / dune zone.

Wide scattering of the samples is also seen by the plot of graphic skewness vs graphic kurtosis (Fig. 4B). However, on superimposing the BVT boundary Friedman, (1961) on the Fig. 4 (B), the JB sediments fall within the area of the riverine environment, whereas the AB and VB samples indicate beach environment. Following Tucker and Vacher's (1980) opinion, taking into account the field

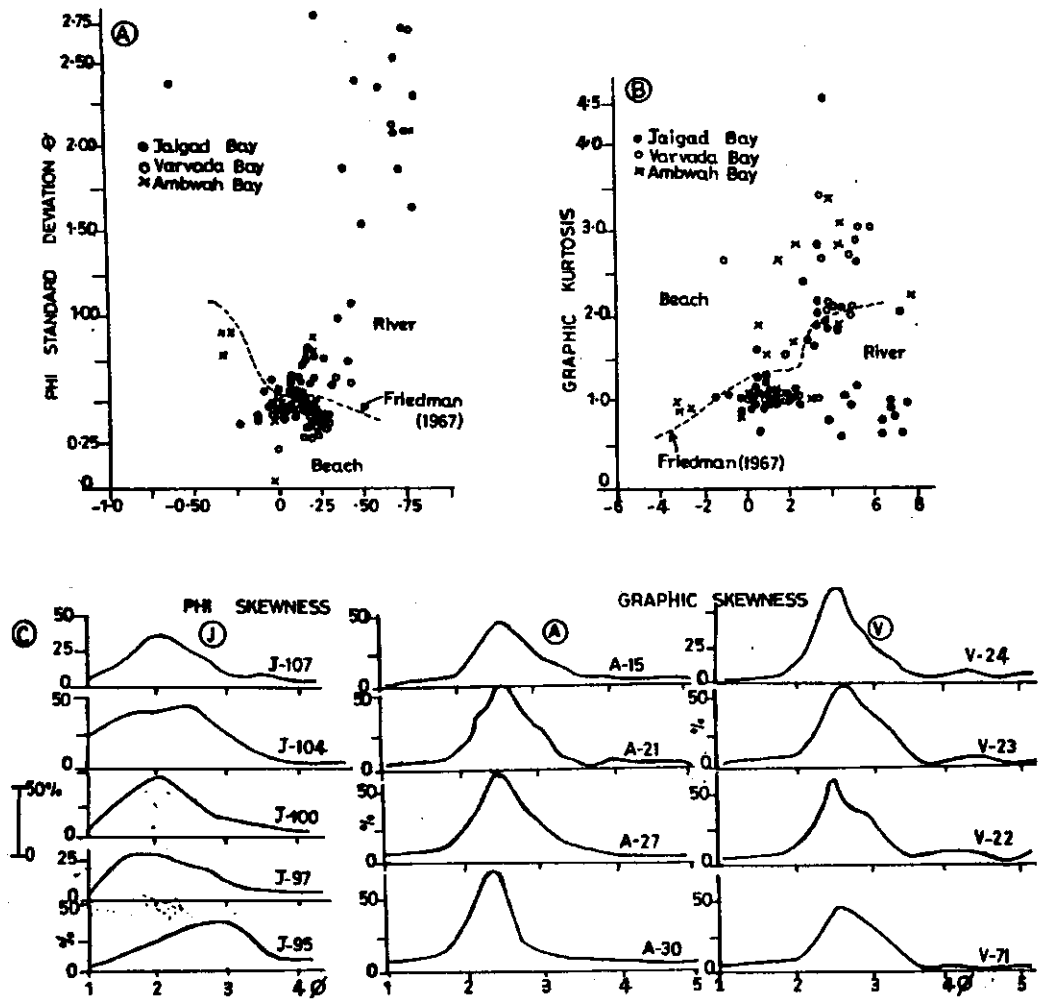


Fig.4. Scatter plot of (A) phi skewness (Third Moment) vs standard deviation (Second Moment). (B) Graphic skewness vs graphic Kurtosis. (C) Plots of phi skewness vs phi mean.

evidences, JB sediment have been assigned to a riverine environment.

The plot of inclusive standard deviation vs inclusive skewness has shown that the JB samples are concentrated in two places: one in the 0.5 ϕ standard deviation zone and the other 1.0 ϕ zone but the other two bays samples are found to be gathered within the zone of 0.5 to 1.0 ϕ values of standard deviation (Fig. 5A). When the boundaries of Friedman (1967) and Moiola & Weiser (1968) are superimposed, an

overlapping of beach and river environments are seen. However, keeping the field evidence and influence of the existing depositional environments, the two areas, viz., JB and the other two bays are shown separately by a tentative dashed boundary line of the author. Taking into advantage, the presence of the JB samples just in the mouth of river deposition, a tentative boundary is marked by dashed line in Fig.5 (B) enclosing the samples of JB to mark the river environment. It shows a well

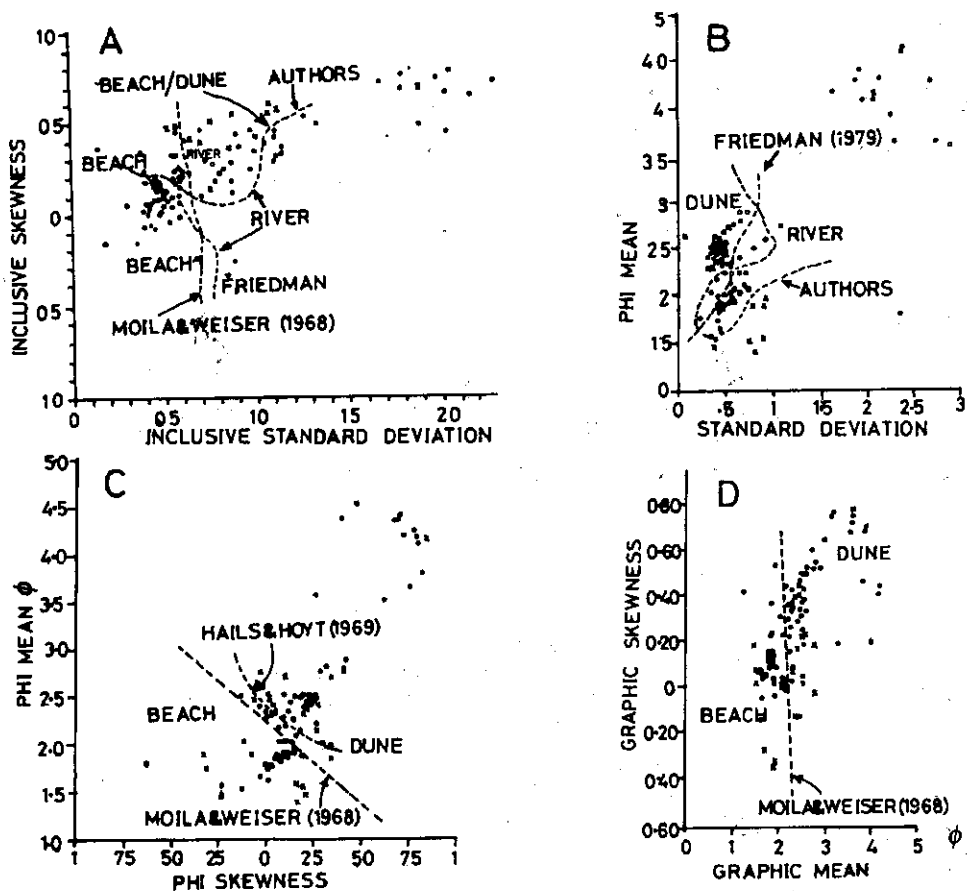


Fig.5. Scatter plot of (A) inclusive standard deviation vs inclusive skewness (B) First moment mean vs standard deviation (C) Skewness third moment vs mean first moment and (D) Graphic mean vs graphic skewness.

defined grouping of VB samples around 2.50 while AB samples are found to have been divided into two different groups, one with lower mean values (2.0ϕ) and the other with higher mean values (2.5ϕ). In the same figure, if the boundary of Friedman (1979) is superimposed, more or less a similar pattern demarcating most of the JB samples and few AB samples in the river environment and the complete VB and a major part of the AB samples in the dune environment is obtained.

The plots of phi skewness vs phi mean (Fig. 5C) and graphic mean vs graphic skewness (Fig. 5D) a dashed boundary line following Moiola and Weiser (1968) is drawn in the

latter. From these plots, the depositional environments are identified as dune to VB, dune / beach to AB and beach to JB.

The study on the basis of the bivariate plots of textural parameters although indicating that sediments of each bay were being deposited in a particular environment, deposition seems to have changed to other environments, as well. Overlapping tendency of the plots lead to the possible subsidiary role of the second environment. Considering the overlap, the environments of the JB sediments are inferred to be influenced by river / beach conditions; while that of AB to beach / dune / river and VB to dune / beach environments.

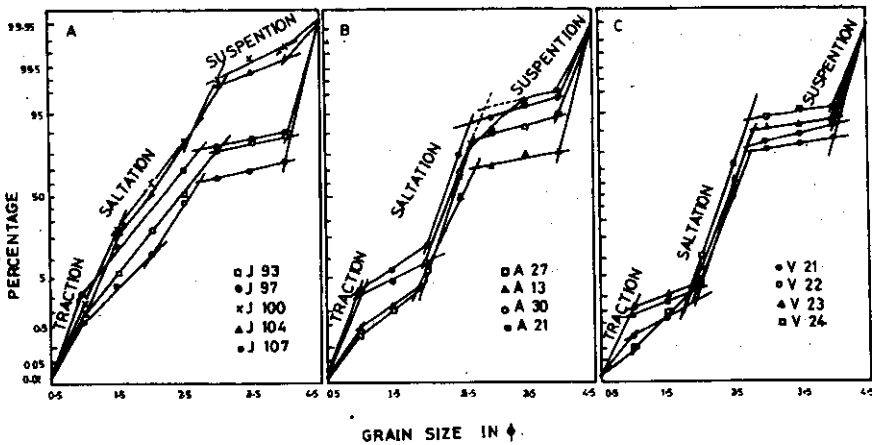


Fig.6. Log probability plot indicating the population break in grain size distribution of sediments from (A) Jaigad (B) Ambwah (C) Varvada Bay.

Multi Group Discrimination Analysis

In view of the overlapping in bivariate plots, an attempt is done to understand the different environments through the multigroup discrimination analysis of Sahu (1983). Accordingly, when it is plotted in Fig.6 for an angle of 94° between the field of optimal discrimination plane bounded by V₁ and V₂, it suggests a single environment of beach.

Arithmetic Probability Curves

Visher (1969) has produced characteristic grain size distribution plots on arithmetic probability paper and marked the coarse truncation (CT) and fine truncation (FT) points, and specific ranges of the percentage distribution of saltation, traction and suspension populations, to the sands from several modern environments such as dune, beach, river, delta, tidal channels, turbidity current, etc. He has also proposed that the segmented nature of the curves is the result of several log-normal sub-populations and shaped by different mechanisms of transport. The data on representative samples from JB, AB and VB are plotted on arithmetic probability paper to obtain C.T. and F.T.

The JB sediments indicate well developed

suspension population, comprising upto 20 percent of the distribution. The FT occurs between 2.75 and 4.0φ. The size in the saltation population is upto 3.0φ. The sample plots illustrate only two populations resembling to the channel deposits.

The probability curves of AB samples show distinctly two types of saltation populations which are related to swash and back-wash in the foreshore zone or mixing of separate provenances or particles of different angularities and roundnesses. The saltation population is about 90 percent, and C.T. is around 0.75φ, whereas F.T. is around 3.75φ. The suspension population is about 2 percent. The C.T. occurs between 0.5 to 1.5φ. The presence of swash and back-wash and the shape of frequency curves, obtained by the author closely resembles the features of the curves for beach environment.

The curves of VB samples unlike those of other two bays show only three populations with good truncation C.T. occurs between 1.0 and 2.0φ. The traction population is less than 2 percent. Along with the suspension populations, accounting for the positive skewness, characterise the dune deposits. Absence of the past aeolian process to move a coarse popula-

tion by surface creep (by rolling) along the surface is indicated by the presence of negligible amount of traction population. The pres-

ence of 4 to 14 percent of suspension population suggests the operation of uni-directional fluvial transport.

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